National Environmental Health Measures for Minority and Low Income Populations:

Tracking Social Disparities in Environmental Health

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Executive Summary

Healthy People 2010 (USDHHS, 2004) has established as a top priority the elimination of health disparities. Current research suggests that characteristics of the social, physical and built environment contributes to these disparities. In order to track progress and to assess the potential contributions of the various components of the "environment," tools specific to environmental health disparities are required.

In this paper, we discuss one potential tool, a set of candidate indicators that may be used to track disparities in outcomes, as well as indicators that may be used analytically to assess potential causal pathways. Several other reports on health and environmental indicators have been produced, including EPA's *America's Children and the Environment*. However, there has not been a comprehensive discussion about environmental indicators that focus on racial, ethnic and socioeconomic disparities in health. Therefore, we focus on indicators specific to historically disadvantaged populations.

Based on a conceptual framework that views health disparities as partially driven by differential access to resources and exposures to hazards, we group the indicators into four categories: social processes, environmental contaminants/exposures, bodyburdens of environmental contaminants, and health outcomes. We provide a few examples to illustrate each category, including residential segregation, $PM_{2.5}$ exposures, blood lead and blood mercury exposures, and asthma mortality. These indicators and categories are derived from a review of environmental health disparities from several disciplines.

As a next step in a long-term effort to better understand the relationship between social disadvantage, environment, and health disparities, we hope that the proposed

indicators and literature review serve as a foundation for EPA to create a databook on environmental health disparities. These efforts may aid community organizations, local agencies, scientists and policy makers in allocating resources and developing interventions.

Questions to Consider:

1. What environmentally mediated health outcomes should EPA track in order to assess health disparities and potential progress?

2. What are some of the key markers of environmental toxicants and hazards that can should be tracked over time?

3. What are some of the key markers of the social environment that can be tracked over time?

Abstract

Healthy People 2010 (USDHHS, 2004) has established as a top priority the elimination of health disparities. Current research suggests that characteristics of the social, physical and built environment contributes to these disparities. In order to track progress and to assess the potential contributions of the various components of the "environment," tools specific to environmental health disparities are required.

In this paper, we discuss one potential tool, a set of candidate indicators that may be used to track disparities in outcomes, as well as indicators that may be used analytically to assess potential causal pathways. Several other reports on health and environmental indicators have been produced, including U.S. EPA's *America's Children and the Environment*. However, there has not been a comprehensive discussion about environmental indicators that focus on racial, ethnic and socioeconomic disparities in health. Therefore, we focus on indicators specific to historically disadvantaged populations.

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Introduction

There is continuing concern that minority and economically disadvantaged populations bear a disproportionate share of environmental exposures and related illnesses. These issues first gained national attention through publications such as the 1987 report by the Commission on Racial Justice of the United Church of Christ, *Toxic Waste and Race in the United States (1987)*, and *Dumping in Dixie: Race, Class and Environmental Quality (1990)* by Dr. Robert Bullard. A 1990 University of Michigan conference on "Race and the Incidence of Environmental Hazards" pressured the U.S. Environmental Protection Agency (EPA) to establish an Office of Environmental Equity (Brown 1995). In response to the growing environmental justice movement, President Clinton, in 1994, issued Executive Order 12898 requiring all federal agencies to work towards ending the disproportionate exposures of minority and poor people to many environmental hazards. A wide range of activities have been undertaken by various sectors of U.S. society to address inequality in exposures to environmental hazards, including: federally funded research programs on environmental hazards, initiatives to increase citizen involvement in environmental decisions, and community-based efforts to address local concerns about environmental hazards. However, it is difficult to evaluate the success of these efforts, especially with regard to eliminating the disparities between minority and majority communities. This is because the tools needed to understand and assess disparities have not been fully developed.

A brief note about terminology is in order. *"Health disparities"* and *"racial disparities"* will be used interchangeably to refer to gaps in morbidity and mortality between racial and ethnic groups. *"Ethnicity"* refers to cultural groups, as in the case of Hispanics, while *"race"* refers to the socially constructed groups specified by Directive 15 of the Office of Management and Budget, namely African Americans, Asian Americans, Native Americans, Pacific Islanders, and Whites (U.S. Office of Management and Budget 1997). As noted by Directive 15 and numerous scholarly organizations, racial and ethnic groups are social categories and not biological taxons. The term *"environment"* encompasses the natural, built and social worlds. Thus, the concept of environmental influences is not limited to physical (e.g., radiation), chemical (e.g., lead), and biological (e.g., pathogens) agents, but also includes social stressors (e.g., fear of crime), institutional processes (e.g., housing policy), and resiliency factors (e.g., social capital). Finally, we use the terms "indicators" and "measures" interchangeably in this document. Some have suggested that indicators denote an etiological process, whereas measures are more descriptive. However, we do not distinguish between the two because the use of a particular variable etiologically or descriptively depends upon the research question.

The Need: Tracking Disparities in Environmental Health

The lack of tools for measuring important elements of environmental health and environmental justice issues, including health status and sociodemographic characteristics, has been a concern since the early 1990s (Sexton, Gong et al. 1993; Sexton 1997; Institute of Medicine (IOM) 1999; Northridge, Stover et al. 2003). Several observers (Bullard and Wright 1993; Lee 2002; Shepard 2002) have speculated that the totality of environmental conditions — whether from exposure to chemical toxins or the availability of healthy food products or the opportunities for gainful employment — contributes to health. However, little empirical research has evaluated the relative weights of these factors. Because the field of research is still nascent, standardized ways of measuring environmental conditions, especially as relevant to ethnic minorities, are lacking. As a result, fundamental questions about the relationship between race, social class and the environment remain unanswered. The challenge is to find valid and reliable measures of environmental risk factors (exposures, susceptibilities, distribution of hazards) and health outcomes associated with environmental hazards that can be applied nationally. One approach to begin to address these issues is the development of indicators to track environmental health disparities.

Previous Indicators

The concept of health indicators or measures is not new to public health. Health indicators are basic tools that public health practitioners use to characterize community health and assess trends in risk factors, mortality and morbidity (Thacker and Berkelman 1988; Thacker, Parrish et al. 1988). Health indicators have been incorporated into national health planning activities such as Healthy People 2010, the guidebook for monitoring the public's health. Goal 8 of Healthy People 2010 is to "promote health for all through a healthy environment." Related to this goal are 30 indicators (objectives) that include: ambient air quality, water quality, toxics and waste, healthy homes, infrastructure and surveillance of environmental health conditions. Of these indicators, five are constructed to describe conditions for racial and low income populations: ambient air quality, lead and radon testing, blood lead levels of children, water quality, and sanitation in U.S.-Mexico border communities. Healthy People 2010 also provides a cross- listing of goals/objectives related to the environment, including reductions in heart disease, respiratory diseases, low birth weight rates, kidney disease and tobacco smoke for which racial/ethnic stratifications of the data are presented. Health indicators have been discussed in a variety of other reports too (Rothwell, Hamilton et al. 1991; Pew Environmental Health Commission 2000; Centers for Disease Control 2003).

Recent applications of environmental health indicators at a national level include EPA's report *America's Children and the Environment: A First View of Available Measures* (Woodruff, Axelrad et al. 2000) and the second edition *America's Children and the Environment: Measures of Contaminants, Body Burdens, and Illnesses* (Woodruff, Axelrad et al. 2003), *and EPA's Draft Report on the Environment* (U.S. Environmental Protection Agency 2004) (see website www.epa.gov/indicators/roe/index.htm). *America's Children and the Environment* presents data on trends in levels of environmental contaminants in air, water food, and soil; concentrations of contaminants measured in bodies of children and women; and childhood illnesses that may be influenced by exposure to environmental contaminants. Although these reports touch upon disparities, applications relevant to racial minorities and low socioeconomic groups are underdeveloped.

Because the development of environmental health indicators has been undertaken by various entities and published in separate reports, a broad understanding or public debate about measuring the environmental impact on the health of ethnic and racial minorities has not taken place to date. We seek to build upon this previous work by compiling the extant information relevant to the study and monitoring of environmental health disparities.

Our Approach

Developing a parsimonious set of indicators for environmental health disparities is a daunting task. The list of potential indicators representing health and environment conditions is nearly endless. In reviewing previously published indicators, it quickly became clear that our first step would be to find a way to conceptualize and group indicators. This would help provide some coherence to the patchwork of indicators available. Therefore, our first task was to review the literature and develop a framework from which to understand how environmental conditions may contribute to health disparities. We reviewed (Gee and Payne-Sturges, 2004) recent scientific literature on health disparities, psychosocial stressors and resources, environmental justice, vulnerability/susceptibility to environmental exposures (e.g. pre-existing health status, occupational exposures), and past work by U.S. EPA, HHS and CDC. The literature review suggested a framework that views health disparities as partially driven by differential access to resources and exposures to hazards. In the present article, we show the next logical sequence to this work by presenting a summary of candidate indicators informed by the framework (Gee and Payne-Sturges, 2004).

One of the purposes of environmental health indicators proposed by the Pew Environmental Health Commission, CDC and Council of State and Territorial Epidemiologists (CSTE) is to facilitate prevention of known or suspected adverse public health events associated with environmental exposures and to detect new adverse health events associated with environmental exposures. In identifying the health outcomes for our candidate indicators we took this preventive view. There are few diseases for which clear environmental etiologies have been established. The difficulties in establishing causation are not unique to environmental health. We do not know with certainty all the causes or risk factors for many chronic diseases. Identifying specific environmental causes of disease is often hampered by long latency; lack of unique markers; and multiple causes. Although disease outcomes have been linked to many biological and physical agents, very few of the millions of known chemical agents have been studied adequately (Thacker, Stroup et al. 1996). For the prevention of illness and the promotion of the public health, we need to track not only diseases, but also the social and physical risk factors for disease (Centers for Disease Control 2003). The surveillance of health outcomes will allow for assessments of public health progress, and the surveillance of risk factors will allow for the study of etiological mechanisms and for the prediction of potential epidemics. For example, identification of a rise in the use of pesticides or an increase in pesticide exposures (a risk factor) may suggest a future increase in the outcomes of unintentional poisonings.

These candidate indicators are presented to *stimulate dialogue* on the choice of appropriate indicators, feasible and defensible methodologies, and elucidation of etiological mechanisms. Undoubtedly, these issues will be best resolved through public debate with community members, scientists, and policymakers.

The Framework

Previously, we reviewed some of the potential factors that might explain environmental health disparities (Gee and Payne-Sturges 2004). The literature suggests that one reason that racial groups differ in health outcomes is because persons of color experience greater exposure to health risk factors (Lee 1993; Sexton, Gong et al. 1993; Williams and Yu 1997; Geronimus, Bound et al. 1999; Williams 1999; Geronimus, Bound et al. 2001; Williams and Collins 2001), due at least in part to the fact that Whites and minorities often do not "work, live and play" in the same places (Lee 2002). People of color are more likely to encounter high risk settings, including residence in high poverty neighborhoods and employment in more hazardous occupations (Wilson 1996; Jargowsky 1997; Williams 1999). Thus, differences in *settings* contribute to increased risk for illness among minority populations.

Given this broad framework, a major challenge lies in defining the types of risks that would be most useful for tracking progress in reducing health risk to minority populations. For tracking purposes, at the minimum, we need indicators of health that are stratified by race, ethnicity and social class. For example, we could track mortality due to lung cancer separately for each racial group. We emphasize that stratifying by race, ethnicity and social class is critical, since disparities cannot be identified if the data are aggregated by these characteristics.

In addition to tracking progress, we also strongly urge the collection of indicators that may be used analytically. For example, some have suggested that the proximity to hazardous landfills may account for racial health disparities. Proximity is not an "outcome" per se, but may be part of the causal pathway. By tracking these potential analytic factors, we are able to test hypotheses that may explain observed disparities.

From an environmental standpoint, the most basic types of measures would include health outcomes and environmental contaminants and hazards. Embedded in the concept of the environment are risks associated with both the physical environment (e.g., soil lead), as well as the social environment (e.g., the distribution of wealth). Recent research has also emphasized measures of bodyburdens of chemical toxicants. Following this reasoning and building on the categories proposed by Thacker (1996), we organize our indicators into four broad categories: **social processes**, **physical environmental hazards/exposures**, **bodyburdens** and **health outcomes.** Table 1 presents definitions for each category. The four categories of indicators are complementary and it may not be necessary (or even possible) to monitor or track all four for a particular issue. In reality the lines drawn to link the boxes in the framework are not straight and clear, but rather "fuzzy" and complex (see Figure 1). Exposure to one environmental contaminant may lead to multiple health impacts and a particular health impact may derive from cumulative exposure to many different environmental contaminants interacting with host vulnerabilities and other underlying causes. Ideally, it would be informative to develop measures/indicators that reflect one-to-one relationships between all four indicator categories.

Although there are not sufficient data to fully accomplish this goal, relationships are evident among some measures across the four categories (e.g., segregation and air toxics exposures; lead in housing and blood lead in children). Therefore, the lack of a causative relationship should not limit what is tracked or monitored. Rather scientific evidence that suggests a relationship between social and physical environmental factors and health is used to help identify what is important for tracking environmental health disparities with the flexibility of updating indicators as the science improves.

Candidate Measures

Based on our review of the scientific literature and identification of national health and environmental data sources, we identified 92 candidate environmental public health indicators to assess progress and status of environmental health of minority and low income populations at the national level. Proposed indicators/measures were selected based on the following criteria:

* Must have empirical or theoretical relevancy to environmental health for minority and economically disadvantaged populations;
* Data must be currently available; and
* National-level data must be available.

Within each of the four categories, we identified indicators that have undergone prior research, such as ambient air quality and the levels of lead measured in blood of children. Further, we present a set of novel indicators that may guide future research. The latter include understudied measures of toxicants, such as urinary pyrethroid pesticide concentrations, as well as psychosocial processes that may contribute to unequal exposure, such as residential segregation. Presented in Table 2 is a general overview of the candidate indicators. These indicators cover a broad range of health outcomes, and social and physical environmental factors. For the health outcome, physical environmental hazard, and bodyburden indicators we suggest presenting the data by race/ethnicity and poverty and over time (if the data allow) to show trends in disparities. Because prior research has shown a relationship between segregation and indicators, such as exposure to hazardous air pollutants and hospitalization rates for acute bronchitis and asthma, we propose presenting the data by degree of racial residential segregation for those indicators.

An important characteristic of the candidate indicators is the incorporation of data collected at different "levels." For example, the health outcome and bodyburden data are collected for individuals. The social processes and hazard indicators are derived from community or county level data. These indicators may be populated from national-scale databases/datasets, such as the National Health Interview Survey, National Health Examination and Nutrition Survey, National Science Foundation's General Social Survey, U.S. Census, American Community Survey, American Housing Survey, EPA's Aerometric Information Retrieval System, U.S. Department of Agriculture's Continuing Survey of Food Intake by Individuals (CSFII), National Agricultural Statistics Service, and U.S. EPA Resource Conservation and Recovery Information Systems. For more details on the types of information that can be obtained, please refer to CDC's report *Environmental Public Health Indicators* (Centers for Disease Control 2003).

We discuss a few example candidate indicators below. Other candidate indicators/measures are more or less comparable to what is presented here in terms of data availability and relevance. For a more detailed description and literature review of each candidate indicator, see www.umich.edu/~gilgee/EPA_disparities_indicators_report.pdf.

Health outcomes>respiratory illnesses>asthma mortality

Research informs us that environmental conditions or environmental contaminants lie behind many diseases and disabilities for which there are known racial and ethnic disparities. A large, growing and well documented literature relying on epidemiological studies as well as human and animal exposure demonstrates that ambient air pollutants contribute to various respiratory problems including bronchitis, emphysema, and asthma (McConnell, Berhane et al. 1999; American Lung Association 2001; McConnell, Berhane et al. 2002). For example, numerous reports have documented significant increases in asthma morbidity and mortality in U.S. beginning in the 1970s, with African Americans disproportionately affected (Ostro, Lipsett et al. 2001; Mannino, Homa et al. 2002). African American and Puerto Ricans have the highest rates of active and lifetime asthma compared with other racial/ethnic groups (Carter-Pokras and Gergen 1993). Gergen et al. (1988) noted that increased prevalence of asthma among African-American children was not explained by socioeconomic status (SES). In another study, Smith et al analyzed the independent and joint effects of race/ethnicity and income-to-federal poverty level (FPL) ratio, adjusting for demographic covariates on parental report of the child ever having been diagnosed with asthma. Furthermore, non-Hispanic Black children were found to be at substantially higher risk of asthma than non-Hispanic White children only among the very poor. Smith et al. (2005) concluded that the concentration of racial/ethnic differences only among the very poor suggests that patterns of social and environmental exposures must overshadow any hypothetical genetic risk.

Pre-existing health conditions may lead to greater vulnerability. For example, epidemiological studies suggest that individuals already suffering from cardiopulmonary conditions, including asthma, chronic obstructive pulmonary disease (COPD) and cardiovascular diseases are at increased risk for developing adverse health outcomes from exposure to air pollution (American Lung Association 2001). Ostro et al. (2001) found air pollution (PM, ozone) was associated with exacerbation of asthma symptoms in a group of African-American children in Los Angeles. McConnell et al. (1999) suggest that children with a prior diagnosis of asthma are more likely to develop persistent lower respiratory tract symptoms when exposed to air pollution in Southern California. In a study evaluating the effects of low air pollution levels, Gent et al. (2003) found that children with asthma were very vulnerable to ozone at levels that are lower than current EPA standards.

Understanding racial/ethnic and income differences in rates of respiratory illness is also important for estimating differential impact of pollution on health. Gwyn and Thurston (2001) took into consideration the baseline rates (e.g. hospital admissions) in the absence of elevated air pollution exposure that differ between subpopulations. Similar relative risks for White and non-White groups would appear to suggest that each population is affected equally by air pollution, but because these groups have different baseline rates these group are not affected equally in absolute terms (e.g. number of excess daily admissions per million persons).

One of the five candidate indicators for respiratory illnesses we propose is asthma mortality. Presented in Figure 2 is the annual rate of asthma deaths from 1980-1999 by race. While death rates for all groups are declining, African Americans continue to have highest asthma mortality rate, twice that of Whites.

Social processes> residential racial segregation

Segregation was one of the four areas of social processes identified that may be especially relevant to environmental health disparities. Residential segregation refers to the process whereby members of racial and ethnic groups live in different areas. The most common measure of segregation is the Index of Dissimilarity (D). D is scored from zero (complete integration) to 100 (complete segregation) and can be interpreted as the proportion of minorities (or Whites) who would have to move in order to integrate a given metropolitan area (Massey and Denton 1993)(Formulas for D can be found in Massey and Denton 1993). In the year 2000, about two-thirds of all African Americans, and roughly half of all Hispanics and Asian Americans and Pacific Islanders would have to interchange residences with White counterparts in order to fully integrate metropolitan areas in the United States (Massey 2001).

Segregation is associated with a variety of health outcomes. Studies have documented a positive association between segregation and infant mortality (Laveist 1989; Polednak 1991; Laveist 1993; Polednak 1993), adult mortality (Polednak 1993; Fang, Madhavan et al. 1998; Hart, Kunitz et al. 1998), life expectancy (Potter 1991), homicide (Shihadeh and Flynn 1996), all cause and cancer mortality (Collins and Williams 1999), and tuberculosis (Acevedo-Garcia 2001). Lopez (2002) found that residential segregation was associated with model estimates of air toxic exposures, even after controlling for poverty, population density, neighborhood industry, and vehicular use.

It has been hypothesized that segregation concentrates social disadvantage (e.g. poverty), which in turn, leads to health outcomes (Massey and Denton 1993; Williams and Collins 2001; Gee 2002). Compared with Whites, minorities are overrepresented in neighborhoods with diminishing and constrained economic opportunities (Wilson 1987; Jargowsky 1997). For example, in Los Angeles in 1990, only 4.9% of Blacks lived in high job growth areas, compared to 52.3% of Whites (Pastor 2001). The concentration of minorities in poor areas contributes in part to socioeconomic differences between Blacks and Whites (Massey and Denton 1993).

Cutler and Glaeser (1997) estimated that a one standard deviation decrease in segregation (13%) would eliminate one-third of the Black-White differences in education and employment. Thus, segregation may be partly responsible for the production of class differences between African Americans and Whites (Williams and Collins 2001). A fuller discussion of segregation and environmental health disparities can be found in Gee and Payne-Sturges (2004) and the accompanying document by Morello-Frosch and Lopez. Segregation might be an indicator used to track environmental health disparities . The degree of residential segregation can serve as an indicator of general community vulnerability and can be combined with data on environmental pollutants (e.g. ambient air pollutants).

Figure 3 shows Dissimilarity between Whites and other minority groups (African Americans, Asian Americans, Hispanics, Native Americans, Pacific Islanders) for metropolitan areas. Segregation for African Americans has declined slightly between 1980 to 2000. However, at a national dissimilarity value of 64, African American segregation remains extremely high (Massey 2001). Segregation for Hispanics, Asians remains moderately high and stable between 1980 to 2000. Segregation for American Indians is relatively low and has declined during this period. Healthy People 2010 does not have a public health objective related to residential segregation.

Physical environmental hazards/exposures>ambient air pollution >criteria air pollutants

Air pollution is an important public health problem, associated with premature death, cancer and long-term damage to the respiratory and cardiovascular systems, psychological distress, and negative behavior (Evans, Colome et al. 1988; Sexton, Gong et al. 1993; Evans 1994; Lundberg 1996; American Lung Association 2001; Woodruff, Axelrad et al. 2003; U.S.

Department of Health and Human Services 2004). These are some of the same illnesses for which health disparities have been observed. (Schwartz and Morris 1995; Schwartz 1999; Zanobetti, Schwartz et al. 2000; Gwynn and Thurston 2001; Pope, Burnett et al. 2004; U.S. Department of Health and Human Services 2004).

Spatial patterns of air pollution are generally linked to land-use decisions. Environmental justice activists and communities have often raised concerns about the potential for disproportionate exposure to air pollution among disadvantaged or racial/ethnic minority populations in urban areas due to the proximity of pollution emission sources, such as bus depots, truck distribution facilities, high-volume roadways, waste treatment and transfer stations, and major industrial sources to residential areas (Maantay 2001).

Early analyses of disparities in potential exposure to outdoor air pollution have focused on criteria air pollutants (lead, ozone, particulate matter, nitrogen dioxide, sulfur dioxides, and carbon monoxide). EPA has established National Ambient Air Quality Standards (NAAQS), permissible ambient concentration levels, for these 6 pollutants. The standards are designed to protect the public from adverse health effects that can occur after either short-term exposure (e.g. one- and eight-hour standards for carbon monoxide) or long-term exposure (e.g. one-year standard for nitrogen dioxide). The first EPA report on environmental justice in 1992 summarized an analysis conducted by Argonne National Laboratory indicating that higher percentages of both African Americans and Hispanics than Whites lived in areas with reduced air quality. For instance, 52% of all Whites lived in counties with high ozone concentrations; for African Americans, the figure was 62%, and for Hispanics, 71% (Wernette 1992). Different geographical distribution of racial/ethnic groups could not explain these differences (Wernette). Researchers also noted that income differentials did not account for the difference in proportion of racial/ethnic minorities living in counties where NAAQS were exceeded. A comparison among population groups below the poverty level showed that African American and Hispanic populations were more concentrated in counties with air quality standard exceedances than the poor population in general (Wernette 1992).

For criteria air pollutants, we propose as indicators percentages of US population by race /ethnicity/poverty living in counties in which air quality standards were exceeded for ozone, CO, PM, sulfur dioxide, nitrogen dioxide and lead standards for as many years as possible to show trends. Figure 4 – 6 shows data for one of the candidate indicators, trends in the proportion of population affected by race/ethnicity and poverty group for $PM_{2.5}$ 24-hour standard of 65 µg/m^3. $PM_{2.5}$, particulate matter with particle size diameter of 2.5 microns or smaller, considered fine particles, are able to travel deeply into the respiratory tract, reaching the lungs. Exposure to fine particles can cause short-term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose and shortness of breath. Exposure to fine particles can also affect lung function and worsen medical conditions such as asthma and heart disease. Scientific studies have linked increases in daily $PM_{2.5}$ exposure with increased respiratory and cardiovascular hospital admissions, emergency department visits and deaths. Recent studies suggest that long term exposure to particulate matter may be associated with increased rates of bronchitis and reduced lung function. People with breathing and heart problems, children and the elderly may be particularly sensitive to $PM_{2.5}$. (U.S. Environmental Protection Agency 2005). The trend graph is Figure 4 shows distinct patterns of populations potentially impacted by $PM_{2.5}$ concentrations with Asian and Pacific Islanders showing the greatest proportions affected and White with the lowest . The proportions of Asian or Pacific Islanders and of White Hispanics living in counties exceeding the $PM_{2.5}$ standard are about double those for other race/ethnicity groups (approximately 30 % and 15 % in 1999-2001 and 2003. The affected population was significantly greater in 2002 for all race/ethnicity groups, likely attributable to meteorological conditions particularly conducive to high particulate matter concentrations. In 2002, the percentage of Black Hispanics affected jumped to over 50 %, indicating that the counties newly affected in 2002 had large Black Hispanic populations.

The term Hispanic is often used for comparison between racial and ethnic groups. However, this term usually lumps together many different groups of people which may mask intra-Hispanic differences. To explore this further, we present the same data on $PM_{2.5}$, but for all the groups that identify Hispanic. As shown in Figure 5, among the Hispanic groups, Mexican Americans have the larger proportion of population, 36%, living on counties where ambient concentrations of $PM_{2.5}$ exceed the24-hr standard. We are able to look at for intra-Hispanic differences because this indicator is geographically based and the Census data, which provides population counts for these ethnic groups, can be linked to the counties.

Additionally, Figure 6 presents data for each racial/ethnic group by poverty status. Poverty threshold levels in 1999 were used and varied from $8,607 (one person under 65) to $36,897 (9 or more persons with no related children). We provide data below poverty, between 100 and 200% poverty and above 200% poverty. As discussed above, Asians, Pacific Islanders, and Hispanics all have relatively large affected population proportions. For the US as a whole, those with higher incomes have a slightly lower tendency to live in counties exceeding the $PM_{2.5}$ standard: < PL 14.7 %; 1-2 x PL 14.2 %; >= 2 x PL 12.6 %. However, this pattern does not consistently apply for all race/ethnicity groups and the proportion affected depends much more on race/ethnicity than on poverty. These indicators for $PM_{2.5}$ were constructed by obtaining ambient air quality monitoring data from EPA's Aerometric Information Retrieval System (AIRS) Air Quality Subsystem (AQS). For each county and year, the maximum 24-hour average concentration across all monitors and days was compared to the 65 μg/m^3, the National Ambient Air Quality Standard for 24-hour average $PM_{2.5}$. If the county maximum exceeds the standard, then the entire county population for that year is assumed to be living in a county exceeding the standard. Otherwise, the entire county population for that year is assumed for this analysis not to be living in a county exceeding the standard, even if there were no monitoring sites or no reported measurements made for that county and year. It should be noted that on average approximately 35% of American Indians or Alaska Natives, 9% of Asian or Pacific Islanders, 9% of Black Hispanics, 19% of Black Non-Hispanics, 14% of White Hispanics and 34% of White Non-Hispanics live in counties where PM air quality was not monitored during the period 1999 – 2003.County populations for 1999 by race/ethnicity were obtained from the Census Bureau

Bodyburden>lead and mercury

Biological monitoring or biomonitoring is the measurement of environmental contaminants or their metabolites either in tissues (e.g. blood, serum or plasma, placenta hair, nails), secreta (e.g. breast milk, urine, feces), expired air or any combination of these, in order to evaluate exposure and health risk compared to an appropriate reference (Maroni, Colosio et al. 2000). Measurements of the levels of pollutants in humans provide direct information about exposures to environmental contaminants.

Lead is the most well known example of a chemical that has been monitored by measuring absorption into human tissue – specifically, lead levels in blood. Elevated levels of lead in the blood of children can cause learning problems such as reduced intelligence and cognitive development (Needleman and Gatsonis 1990; Needleman, Schell et al. 1990; Bellinger, Stiles et al. 1992; Needleman 1994; Metzger, Delgado et al. 1995; Needleman 1995; Needleman 1998; Needleman 2000; Needleman, McFarland et al. 2002; Bellinger and Needleman 2003; Woodruff, Axelrad et al. 2003; Needleman and Landrigan 2004). A blood lead level of 10 µg/dL or greater is considered elevated, but there is no demonstrated safe concentration of lead in blood of children (Canfield, Henderson et al. 2003; Canfield, Kreher et al. 2003; Woodruff, Axelrad et al. 2003). Occupational lead exposure in adults has been associated with anemia, nervous system dysfunction, kidney problems, hypertension, decreased fertility, and increased miscarriages. In addition, workers can bring lead home from their workplace, and unknowingly expose their families (National Institute for Occupational Safety and Health 2003). A national health goal is to eliminate all occupational exposures that result in BLLs >25 µg/dL (National Institute for Occupational Safety and Health 2001). Also researchers have shown that childhood lead exposure may contribute to incidence of high blood pressure later in life (Nash, Magder et al. 2003).

National data on blood lead levels have been collected since 1976 through the Centers for Disease Control and Prevention's (CDC) National Health and Nutrition Examination Surveys (NHANES).These surveys continue to show racial/ethnic and income disparities. For example the 1999 – 2000 survey showed African-American children had the highest median blood lead level at 2.8 µg/dL compared with Hispanics and White children at 2 µg/dL (Woodruff, Axelrad et al. 2003). Children of all racial/ethnic backgrounds living below poverty line had higher median blood lead level than children above poverty (Woodruff, Axelrad et al. 2003).

In addition to monitoring blood lead through NHANES, The National Center for Environmental Health (NCEH) at the CDC measures the bodyburdens of the American public for many other environmental contaminants. Results from these surveys are now being published in a biannual report, The National Report on Human Exposure to Environmental Chemicals. The most recent report was released in January of 2003 and presented biomonitoring data for 116 chemicals and their metabolites (lead, mercury, cadmium, pesticides, cotinine, PCBs, dioxins, etc) including stratification of the data by age, gender, and race/ethnicity. It is expected that as analytical methods improve, NCEH will be able to report on more chemicals.

Given the availability of the bodyburden data by race and ethnicity, the Environmental Justice and Health Union (EJHU) conducted a review of the January 2003 National Report on Human Exposure to Environmental Chemicals report. EJHU found that African Americans are much more likely than other groups to be exposed to dioxins and PCBs and are more likely to be exposed at higher levels; Mexican Americans are much more likely to be exposed to pesticides, herbicides and pest repellants and are more likely to be exposed at higher levels; Non-Hispanic Whites are more likely to be exposed to polycyclic aromatic hydrocarbons (PAHs) and phytoestrogens and are more likely to be exposed to phthalates at higher levels; and African Americans are exposed to the greatest number of chemicals in the study (Environmental Justice and Health Union 2004). The differences in bodyburden are important to understand because they may reflect differences in activities or conditions contributing to exposure that could be altered to reduce/eliminate exposure. While the CDC cautions not to interpret the presence of a chemical in the blood or urine as a marker of disease, bodyburden data do indicate that some exposure has taken place. When there is sufficient toxicological information, some interpretation of risk based on the bodyburden data may be possible (e.g. lead, mercury) (National Center for Environmental Health 2003; Woodruff, Axelrad et al. 2003). An important limitation of these data is that they are cross-sectional, and do not provide information to determine the time or the duration of exposure.

Presented in Figures 7–10 are examples of proposed indicators for bodyburden of lead and mercury. Biomonitoring data from the National Health and Nutrition Examination Survey (NHANES) carried out by the Centers for Disease Control and Prevention (CDC), National Center for Health Statistics (NCEH) is the primary data source. As shown in Figure 7 , median blood lead levels have steadily declined for children of all racial and ethnic groups since 1976. This success has been attributed to the phasing out of lead in gasoline between 1973 and 1995 and to the reduction in the number of homes with lead-based paint from 64 million in 1990 to 38 million in 2000. However, racial/ethnic disparities in blood lead level persist. The median level is consistently higher for the Black Non-Hispanic population and consistently lower for the White Non-Hispanic population. Additionally, based on the 1999-2002 NHANES, the proportion of Black Non-Hispanic children (ages 1 – 5) with blood lead levels above 10 µg/dL is 3.2 % compared with 1.6% for Mexican American , 1.0 % for White Non-Hispanic children (see Figure 8) . A large body of evidence shows that a common source of lead exposure for children today is lead-based paint hazards in older housing and the contaminated dust and soil it generates (Jacobs, Clickner et al. 2002). Although lead in new residential paint was banned in the United States in 1978, lead-based paint still remains in an estimated 38 million dwelling units, according to the U.S. Department of Housing and Urban Development (HUD) (Jacobs, Clickner et al. 2002). Lead in soil and paint is also associated with deteriorating and substandard housing (Silbergeld 1997; Jacobs, Clickner et al. 2002).

Lead exposure for adults is also a concern. Figure 9 shows the proportion of adults (age 18 years and older) with blood lead levels 25 µg/dL or higher by race and ethnicity. Again disparities are evident with Hispanics, principally Mexican Americans, with a larger percentage of the adult population affected. Twenty-two percent of Hispanic adults had blood lead levels > 25 µg/dL as compared with 3% for Black Non-Hispanics and 8% for White Non-Hispanics.

The second example for a bodyburden indicator is blood mercury levels in women of childbearing age (see Figure 10). From the 1999 – 2000 NHANES survey, African American woman had the highest geometric mean of blood mercury concentrations of maternal age women 16 - 49 years. About 8% of all U.S. maternal age women have blood mercury levels > 5.8 ppb, a level considered by EPA to cause increase risk of adverse health effects to babies (Woodruff, Axelrad et al. 2003).

Mercury is a highly persistent, highly bioaccumalative and toxic pollutant. Human exposure to mercury occurs mainly through consuming contaminated fish and shellfish. Studies show that subsistence fishing is more common among racial/ethnic minorities and therefore they are potentially more exposed to contaminants found in fish such as methylmercury (Burger, Pflugh et al. 1999; Burger, Stephens et al. 1999; Burger, Gaines et al. 2001; Burger 2002; Burger, Gaines et al. 2002; Corburn 2002).

Mercury can cause health problems at even low levels of exposure, especially neurological damage to fetuses and children, who are thought to be more sensitive to methymercury's effects because of the enhanced vulnerability of the developing nervous system. Health effects of concern in children include learning deficits. Recent studies show that mercury exposure can also have adverse health effects on the nervous, immune and cardiovascular systems of adults as well as children (Landrigan, Graham et al. 1994; Woodruff, Axelrad et al. 2003).

Discussion of Challenges and Next Steps

Eliminating health disparities is an overarching goal for improving our nation's health. Current research suggests that health disparities are produced by both environmental (e.g. physical, chemical, biological agents to which individuals are exposed in a multitude of settings, including home, school and workplace) and social forces (e.g. individual and community level characteristics such as SES, education, coping resources and support systems, residential factors, cultural variables, institutional and political forces such as racism and classism). Moreover, environmental justice advocacy has encouraged scientists and regulators to take more holistic approaches toward understanding how socioeconomic factors shape distributions of diverse communities and environmental hazards that ultimately impact public health. We present a Framework for Understanding and Tracking Social Disparities in Environmental Health (Figure 1) for understanding the connections between race/ethnicity, environmental conditions and health disparities, which can aid in identifying opportunities for prevention and environmental contributors to health disparities.

We propose the development of a comprehensive set of environmental health indicators/measures to assess/monitor environmental contributors to racial, ethnic and class disparities in health. We expanded on EPA's report *America's Children and the Environmen*t by including measures of social processes (e.g. segregation) that may be useful in understanding environmental health disparities, and by highlighting emerging issues that may be potential avenues for future research. Based on review of literature and available national data sets, we identified 112 indicators/measures that fall into the following topic areas: segregation, neighborhood deprivation, crowding, neighborhood resources, outdoor air, indoor air, ambient water and drinking water quality, land contaminants, biomonitoring and health outcomes. Some of the proposed indicators/measures represent indicators that have been previously reported by other agencies and organizations. For example, several Healthy People 2010 objectives on environmental health, cancer, respiratory disease, and tobacco overlap with our candidate indicators. Because Healthy People 2010 has made the elimination of health disparities, the gap in morbidity and mortality between social groups (eg. racial/ethnic minorities and low-income populations), a top national priority, this overlap increases the relevance of the proposed indicators and provides focal points for federal interagency activity. Some of the proposed indicators/measures represent indicators that have been previously reported by other agencies and organizations. In addition, based on our framework we present a number of novel indicators/measures that integrate social processes with environmental health conditions or highlight new and emerging environmental health issues. Now with these proposed indicators/measures identified, we would like to talk about next steps.

In developing the proposed indicators, we took note of a number of methodological and scientific questions that need to be addressed. Therefore, in moving forward, we suggest engaging stakeholders (federal agencies, environmental health and health disparities researchers, policy makers, community health advocates, etc.) to review the full suite of proposed indicators to assist in: 1) addressing scientific details (e.g. quality of databases, interpretation of indicators); 2) prioritizing/ranking of indicators in terms of usability, importance to environmental health and health disparities, scientific validity and reliability, time scale of data, and geographic and population coverage; 3) identifying additional indicators; 4) identifying data sources to improve population coverage for Native Americans and emerging subgroup groups (e.g. Arab Americans, African immigrants, multi-racial Americans); 5) incorporating occupational exposures and health; 6) addressing the role of risk perception and 7) identifying alternatives or additional approaches to express socio-economic position (e.g. income, poverty level, Gini coefficient) disparities and relevant social processes for the environmental health indicators. One important avenue that should be explored is the potential for multi-level analysis of existing environmental data which may be accomplished by merging environmental datasets with existing individual-level datasets (Diez-Roux, 2002). Please see the accompanying document by Soobader et al. for further discussions about multi-level analyses as applied to environmental health disparities. Continuing dialogue on these issues will further our ability to understand environmental health and to develop effective interventions.

The proposed indicators can facilitate the tracking of environmental health status of disadvantaged populations, aid in assessing the contribution of the environment to health disparities, and inform discussion among policy makers and the public on how to improve data and research on environment and minority health. Specifically for EPA, these indicators will provide the Office of Environmental Justice with tools for identifying and communicating environmental justice issues within a public health context. In addition the indicators will provide critical baseline information for the federal interagency task force on environmental justice and health disparities, co-chaired by Department of Health and Human Services (HHS) Office of Minority Health and EPA's Office of Environmental Justice. Finally, these indicators may provide important information for EPA to consider in conducting risk assessments (population vulnerability has recently been identified by National Environmental Justice Advisory Council and EPA's Risk Assessment Forum Cumulative Risk Tech Panel as an important factor to consider in risk assessment) and in economic cost/benefit and distributional analyses per Executive Order 12898 on Environmental Justice and U.S. EPA's Guidelines for Economic Analysis (Executive Order 12898 1994; U.S. Environmental Protection Agency 2000).

Recognizing that effective public participation in policy decisions and development of interventions to reduce and eliminate health disparities requires public access to information, a report published by EPA on the proposed indicators populated by national data would fill the need for a single document presenting scientific information and data on environmental health in minority and low income populations, similar to EPA's *America's Children and the Environment* report. In publishing such a report, we should be mindful to provide indicators that will be useful for communities, policymakers, and scientists. This report could serve as the national reference point from which state and local agencies could compare their own trends. The ability to reflect trends at a national and local level, over time, and across a diverse set of social and physical factors may provide a key element in the effort to eliminate health disparities.

Table 1 Categories of Indicators

Social Process Indicators or Measures: Psychosocial factors that may directly or indirectly lead to illness. These include factors operating at the interpersonal (e.g. socioeconomic position) as well as societal level (e.g. residential racial segregation).

Physical Environmental Hazards/Exposure Indicators: condition or activities that identify the potential for or occurrence of exposure to an environmental contaminant or hazardous condition (e.g. toxic chemical agents, physical agents, biomechanical stressors, as well as biological agents).

Bodyburden Indicators: biological markers in tissue or fluid that identify the presence of a substance or combination of substances that impact human health.

Health Outcome Indicators: Diseases or conditions that may be related to exposure to an environmental hazard (or environmental pollutant).

Table 2 Overview of Candidate Indicators/Measures

Social Processes	**Physical Environmental Hazards/Exposures**
Residential segregation Dissimilarity Isolation Minority composition Ethnic churning **Community stressors** Crowding & density Crime Noise Lack of control Household poverty Stigma Family income Employment opportunities Housing quality Living standards Income inequality **Neighborhood resources** Social capital Voter participation Neighborhood quality Faith-based institutions Recreational facilities: parks, etc. Greenways Neighborhood associations Schools, libraries Cultural institutions **Structural** factors Zoning policies Governance structure Taxation system Regulatory environment Physical constraints: temperature, elevation, humidity	**Outdoor air pollution** Exposure to Criteria air pollutants Estimated noncancer risks from air pollutant exposures Estimated cumulative cancer risk from air pollutant exposure **Indoor air pollution** Smoking ETS exposure Radon Lead hazards Substandard quality housing Jurisdictions with anti-smoking ordinances for public spaces **Drinking water and ambient water quality** Population served by public water systems not meeting standards Migrant worker camps water systems not meeting standards U.S.-Mexico Border community water systems Access to recreational waters meeting standards Populations in areas with high quality watersheds Populations with in states with fish advisories Fish consumption patterns **Pesticides** Foods with detectable pesticide residues Pesticide related illnesses among agricultural workers Reported pesticide use by farmers Estimated pesticide exposure through fish consumption/subsistence fishing Reports of indoor pesticide use **Land contaminants and waste sites** Population living within 1 and 3 mile radii of hazardous waste sites and landfills Population living within 1 and 3 mile radii of Superfund sites designated as public health hazard
Bodyburden	**Health Outcomes**
Lead (in children and adult workers) Cadmium Mercury (in women of childbearing age) Arsenic Cotinine OP pesticides Pyrethroid pesticides	**Life expectancy** **Mortality** All cause mortality Cancer mortality Asthma mortality Infant mortality

PCBs DDT/DDE Estimated pesticide doses based on body burden measures	**Cancer** Lung cancer Bladder cancer Leukemia Breast cancer **Respiratory Illnesses** Hospitalization rates for respiratory illnesses Sarcordosis Asthma **Other Chronic Diseases** Heart disease Kidney disease Liver disease Hypertension Diabetes Neurological diseases Lupus **Children's Health** Cancer in children Low birth weight Birth defects Childhood asthma **Infectious Diseases** Foodborne and waterborne illnesses

Figure 1

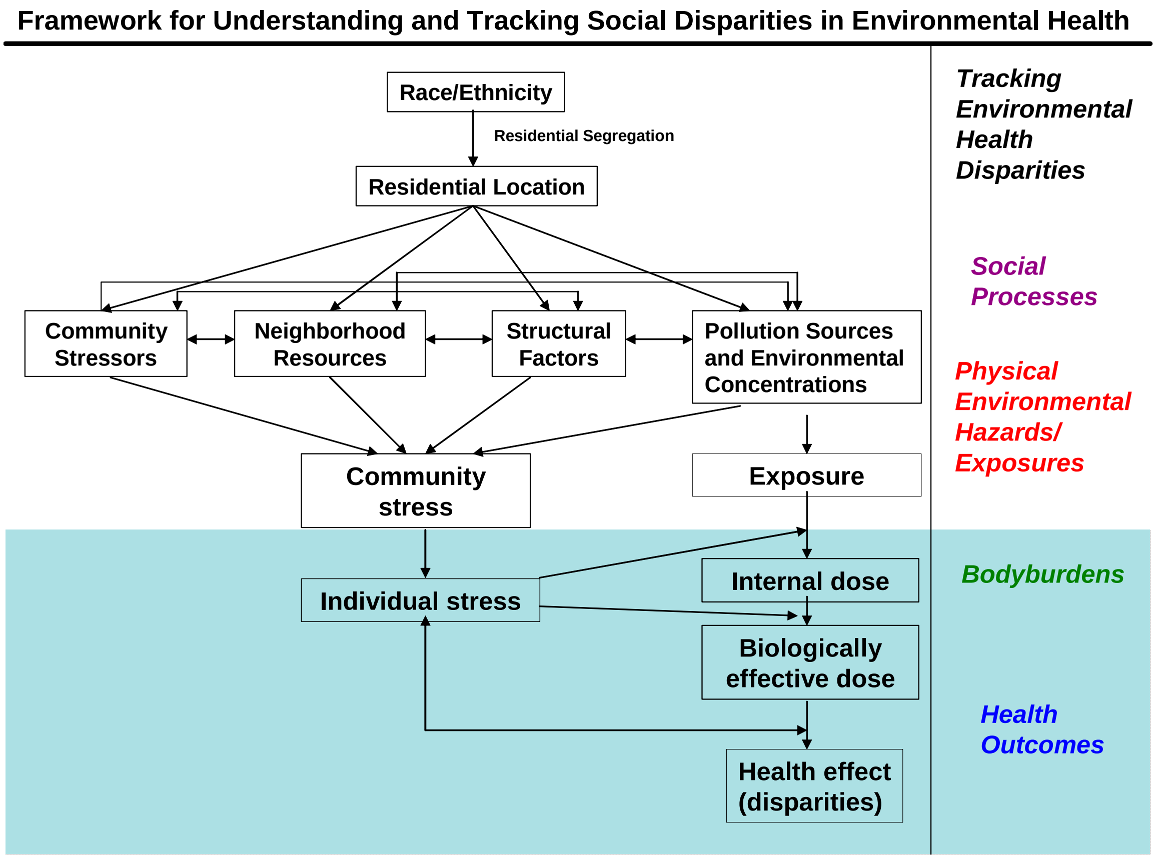

Framework for Understanding and Tracking Social Disparities in Environmental Health
Race/Ethnicity
Residential Segregation
Residential Location
Community Stressors
Neighborhood Resources
Structural Factors
Pollution Sources and Environmental Concentrations
Community stress
Exposure
Individual stress
Internal dose
Biologically effective dose
Health effect (disparities)
Tracking Environmental Health Disparities
Social Processes
Physical Environmental Hazards/ Exposures
Bodyburdens
Health Outcomes

Figure 2 Annual rate of asthma deaths from 1980 - 1999 by Race
Source: National Center for Health Statistics, National Vital Statistics System

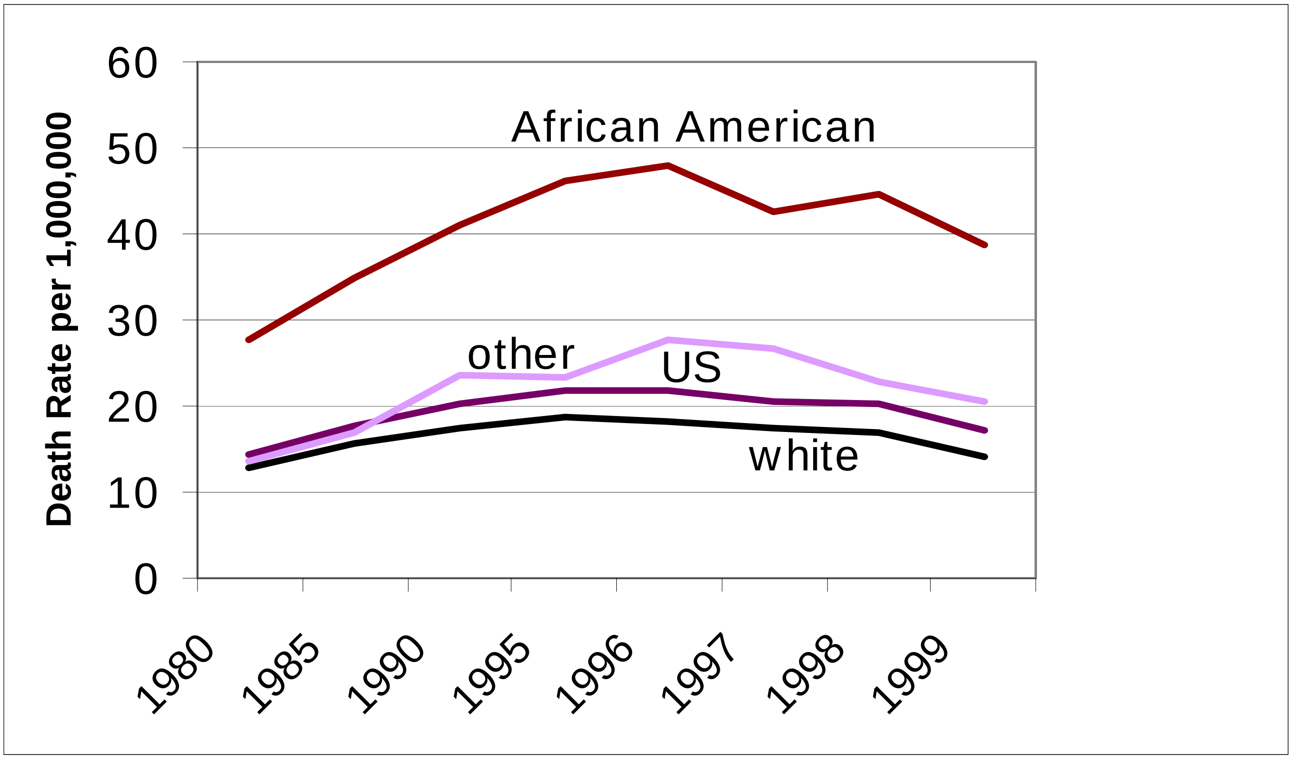


Figure 3

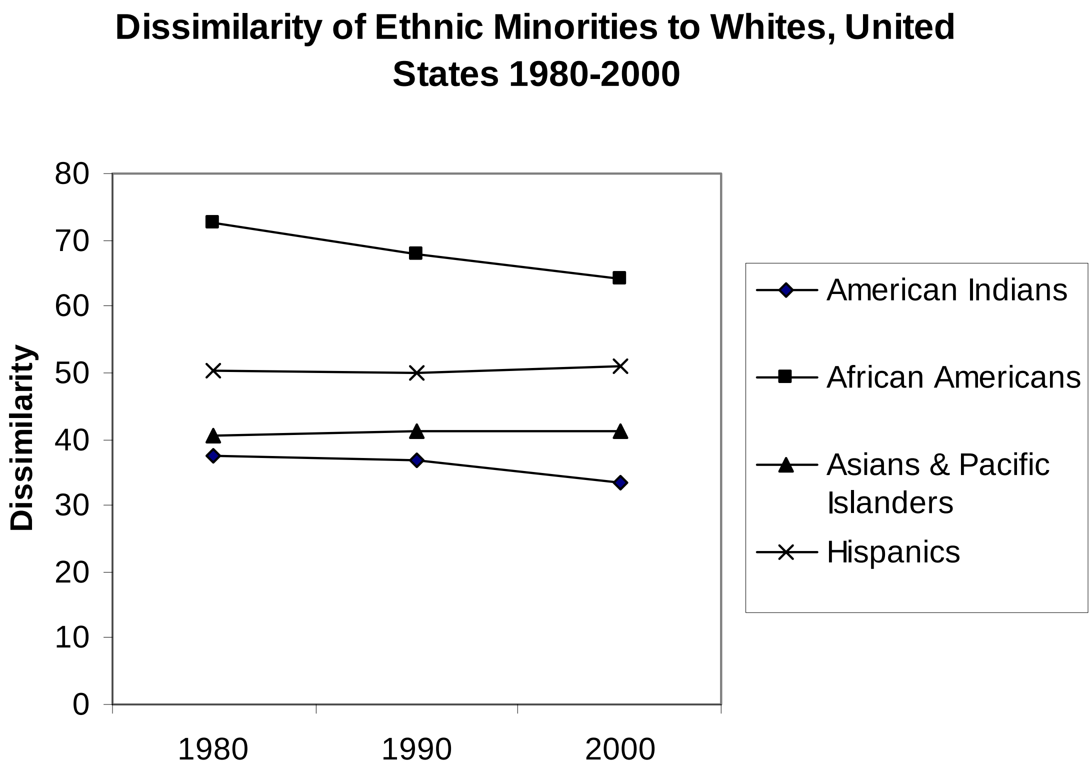

Dissimilarity of Ethnic Minorities to Whites, United States 1980-2000
Dissimilarity
80
70
60
50
40
30
20
10
0
1980
1990
2000
American Indians
African Americans
Asians & Pacific Islanders
Hispanics

Figure 4

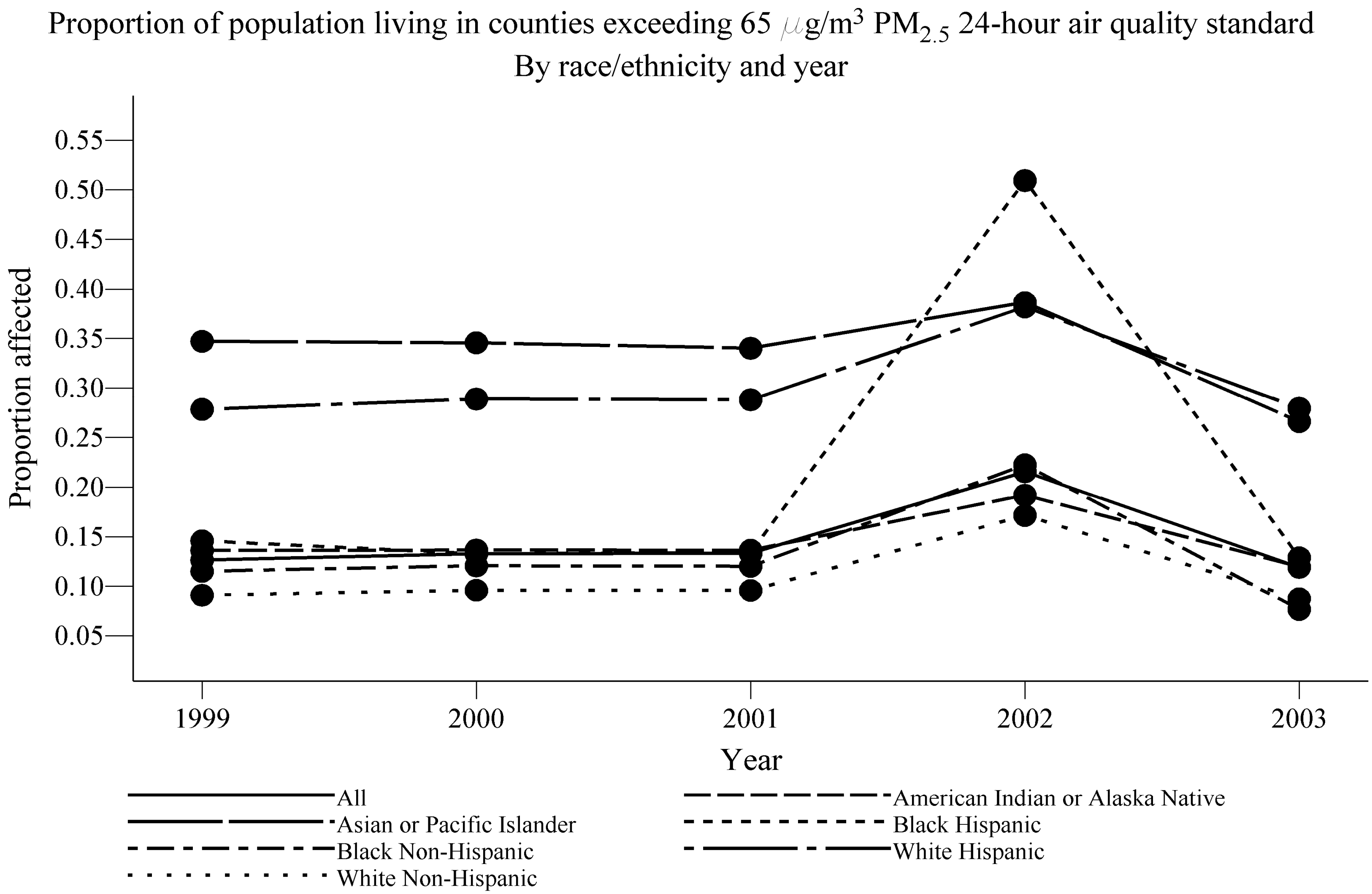
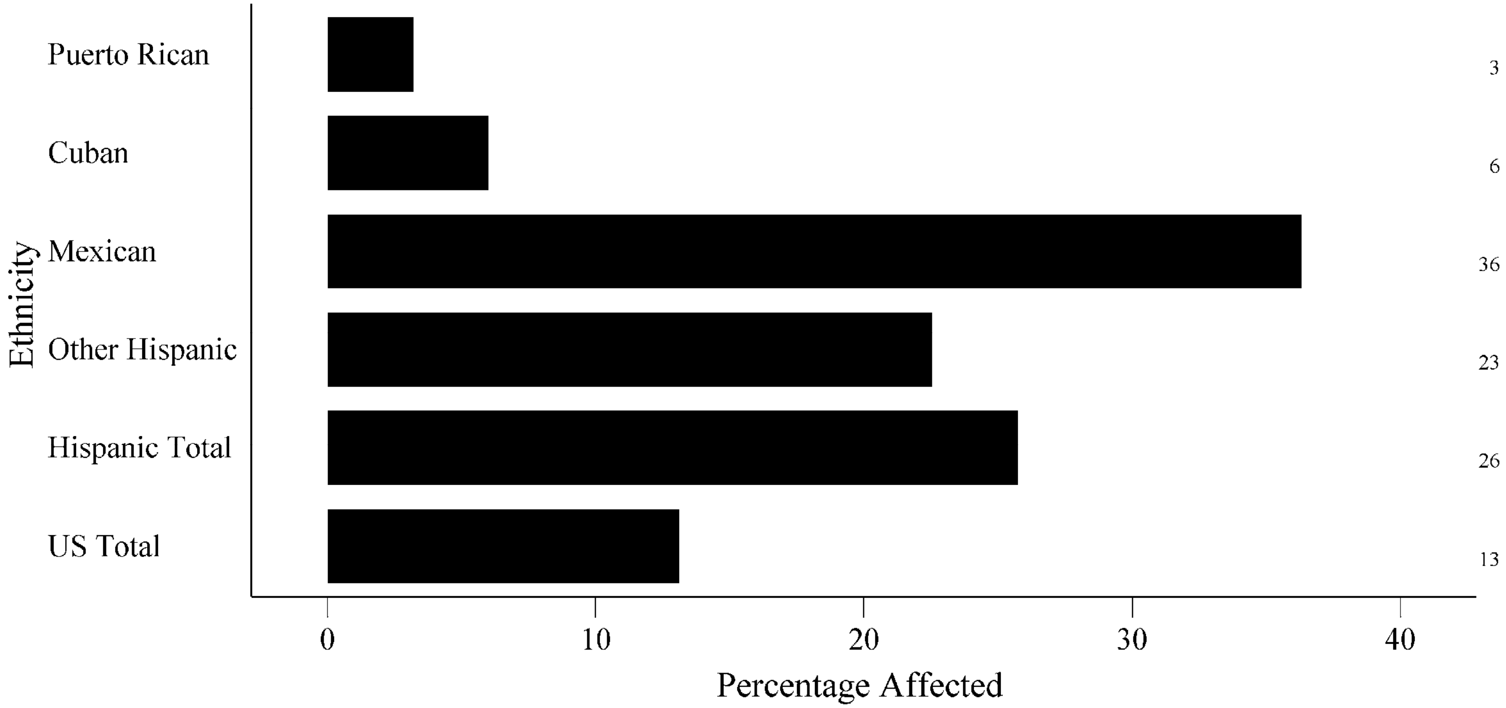

Proportion of population living in counties exceeding 65 μg/m3 PM2.5 24-hour air quality standard
By race/ethnicity and year
Proportion affected
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
1999
2000
2001
2002
2003
Year
All
American Indian or Alaska Native
Asian or Pacific Islander
Black Hispanic
Black Non-Hispanic
White Hispanic
White Non-Hispanic

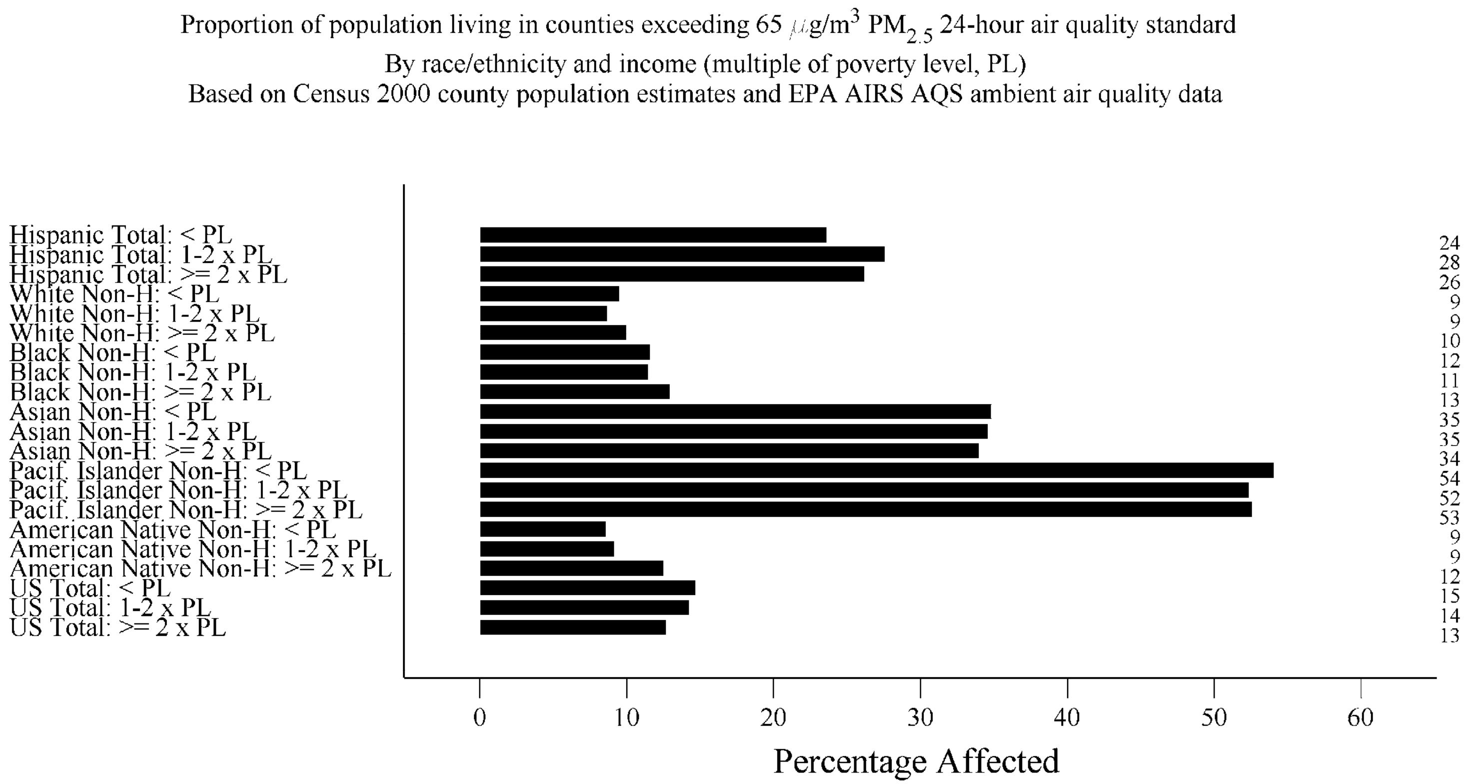
Figure 5

Proportion of population living in counties exceeding 65 $\mu g/m^3$ $PM_{2.5}$ 24-hour air quality standard
For Hispanic populations
Based on Census 2000 county population estimates and EPA AIRS AQS ambient air quality data



Other Hispanic = Dominican, Central American, South American, Spaniard, and all other non-Puerto Rican, non-Cuban, and non-Mexican Hispanic or Latino.

Figure 6

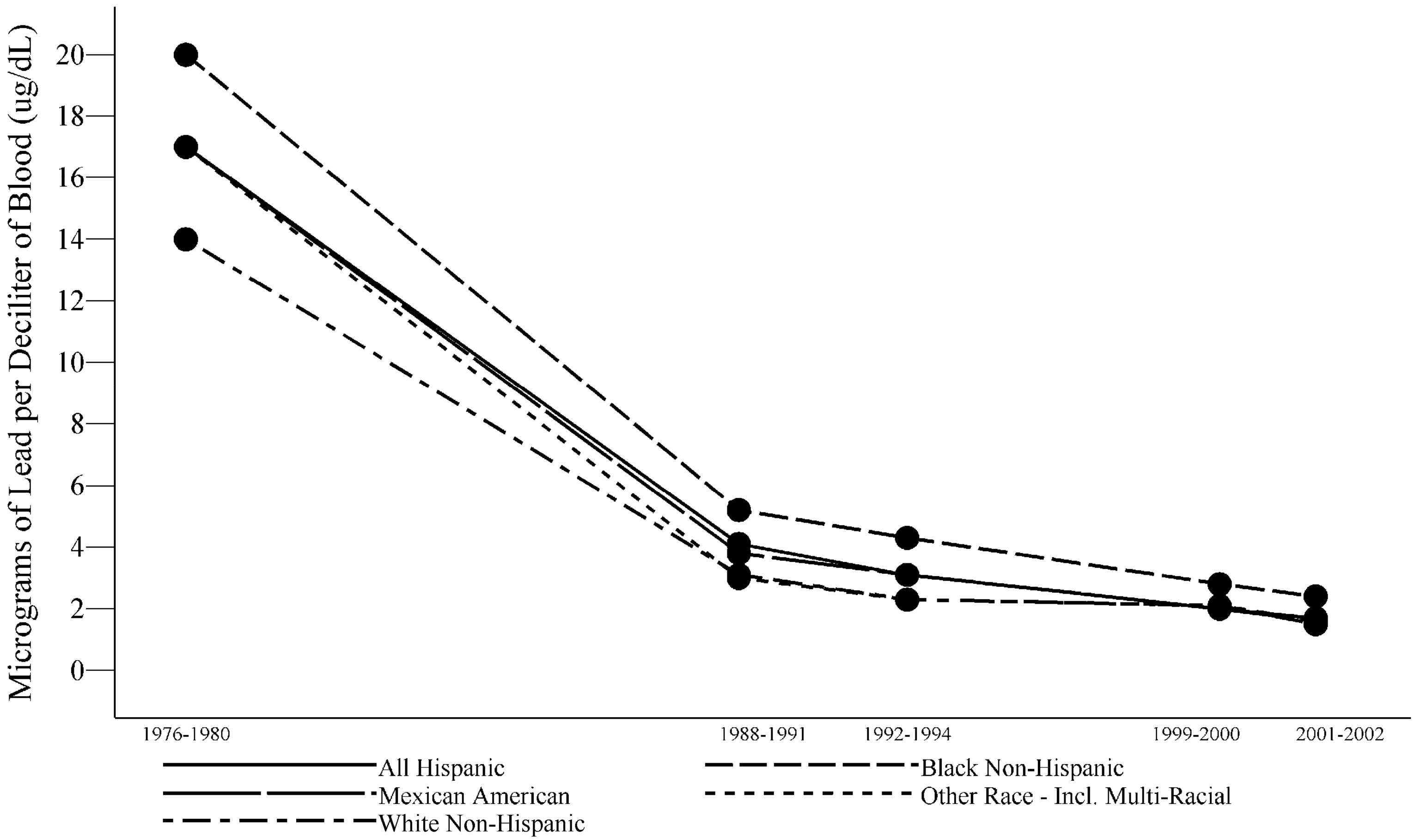


Based on family income and poverty levels for 1999.
The Poverty Level (PL) depends upon total family size, number of children under 18, and,
for families of 1 or 2, whether or not the Reference Person is under 65.
Poverty Levels range from an average of \$8,501 for a family of one to \$34,417 for a family of nine or more.

'< PL' = 'Income Below Poverty Level'
'1-2 x PL' = 'Income Between 100 % and 200 % of Poverty Level'
'>= 2 x PL' = 'Income At Least 200 % of Poverty Level'

Figure 7

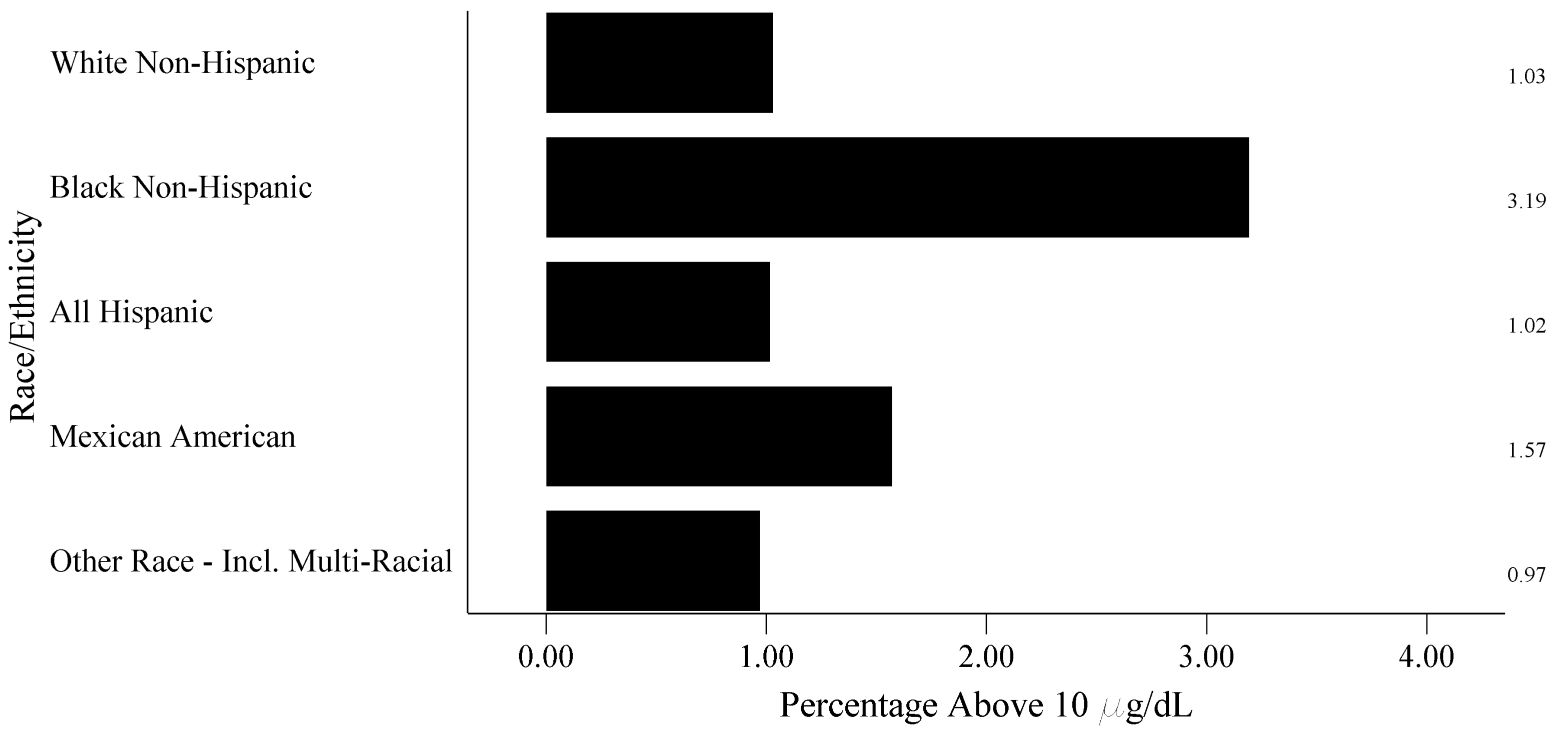
Median concentration of lead in blood for US children between one and five years old



SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey

Figure 8

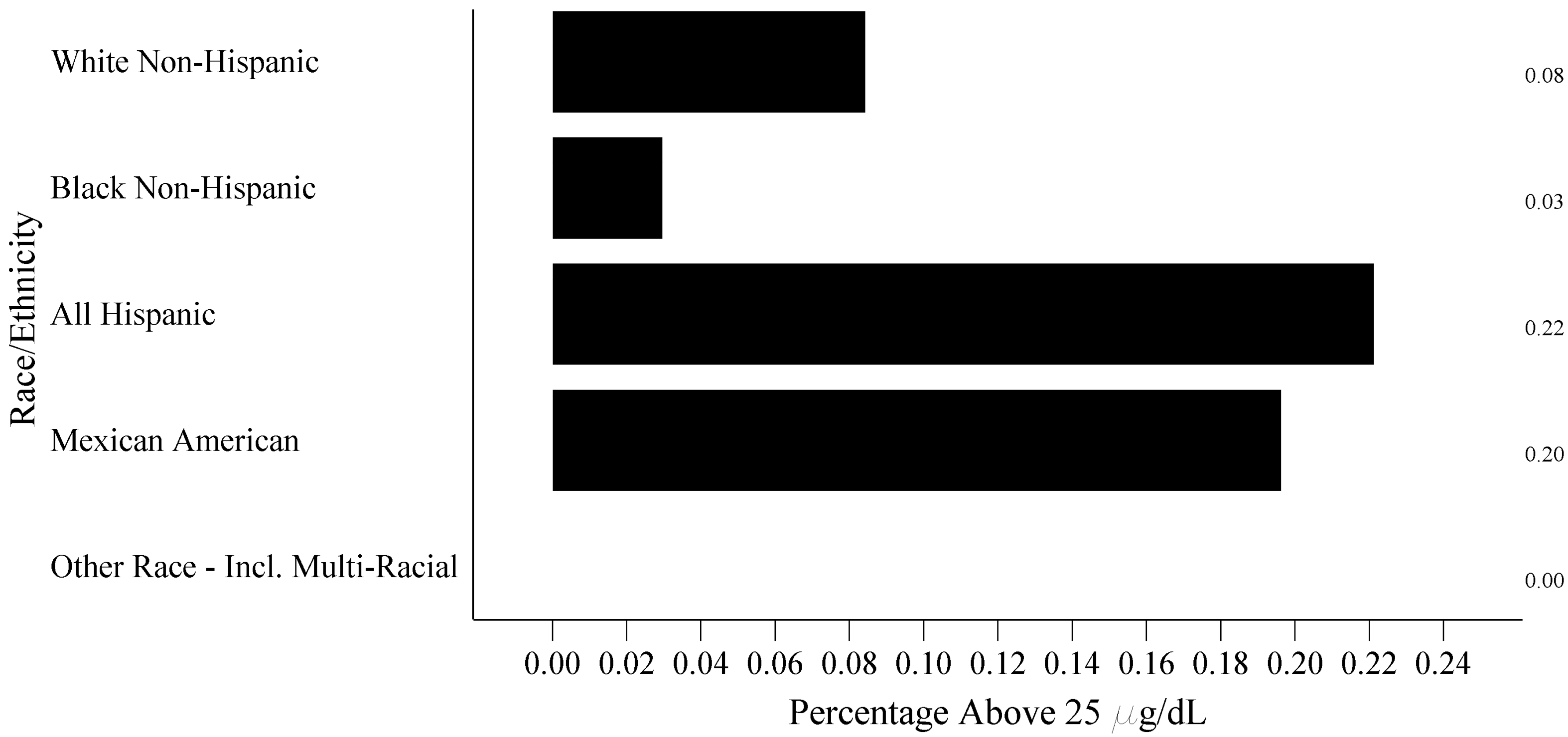
Percentage of US children between one and five years old with lead in blood exceeding 10 μg/dL



SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey 1999-2002

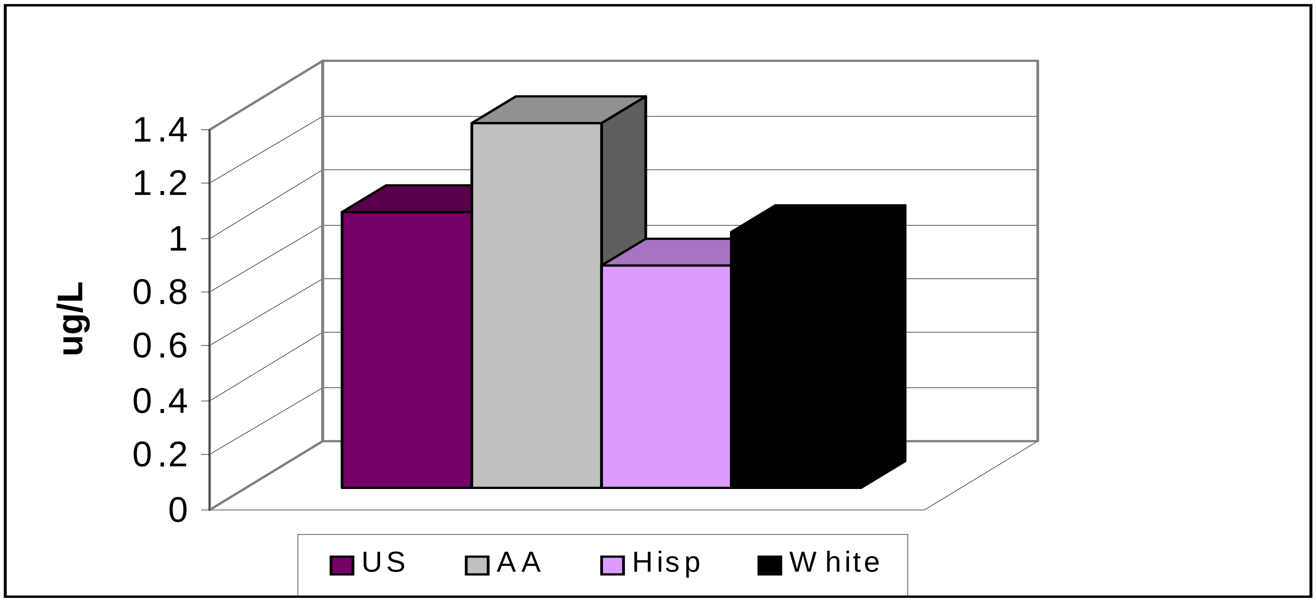
Figure 9

Percentage of US adults with lead in blood exceeding 25 μg/dL



SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey 1999-2002

Figure 10 Geometric mean blood mercury concentrations of maternal age women 16 - 49 years by race/ethnicity



Source: NHANES 1999 - 2000 Survey, NCHS, CDC

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